A method and apparatus for tempering material is provided. One or more liquids are atomized by at least one sprayer into droplets which are guided towards a surface of a hot material so that at least some of the droplets collide with the surface of the hot material and evaporate, thus removing thermal energy from the surface layer of the hot material. Impact members may be used to further reduce the size of the droplets. The droplets may be guided to the surface by a separate guiding gas flow.
METHOD AND APPARATUS FOR TEMPERING MATERIAL

BACKGROUND OF THE INVENTION

[0001] The invention relates to a method according to the preamble of claim 1 for tempering material and to apparatus according to the preamble of claim 16 for tempering material.

[0002] According to prior art, metals, such as steel, glass and other materials are tempered by air cooling. It is also known to temper a piece to be tempered by immersing the hot piece into water. In tempering based on air cooling, a strong flow of air is directed to the material to be tempered or to a surface of a product. The strong flow of air is used with the aim of reducing the temperature of the material rapidly, the structure and/or properties of the material undergoing changes that provide the material with desired characteristics. Steel tempering, for example, is understood to mean heating the steel above the temperature of austenite formation and cooling it, after a holding period required for the austenite formation and homogenization, at a rate faster that the critical cooling rate. The aim with the tempering is a specific, predetermined martensite content in the microstructure of the tempered piece. Glass tempering, in turn, aims at using rapid cooling to produce a compression tension in the surface layer of the glass and a tensile stress into the inner part of the glass.

[0003] A problem with the above prior art solution based on air cooling is that air cooling in connection with tempering requires an extremely large amount of air and an efficient flow thereof towards the surface of the material or product to be tempered. Such a large amount of air and efficient flow consume extremely high amounts of energy. Moreover, in many applications management of rapid and uniform cooling is difficult to control and carry out, particularly when thin pieces, such as thin glass, are being tempered. Hence air cooling and the control thereof for producing an even cooling requires complex hardware solutions. Water tempering, in which a hot piece is immersed into water, is impossible to control on an industrial scale when tempered products of a good quality are to be produced.

BRIEF DISCLOSURE OF THE INVENTION

[0004] It is therefore an object of the invention to provide a method and apparatus that allow the above problems to be solved. The object of the invention is achieved by a method according to the characterising part of claim 1, characterized in that in the method at least one liquid is atomized into droplets, the formed droplets being guided towards a surface of a hot material so that at least some of the droplets collide with the surface of the hot material and evaporate when they receive thermal energy from the surface layer of the hot material. The object of the invention is further achieved by the apparatus according to the characterising part of claim 16, the apparatus being characterized in that the apparatus comprises one or more sprayers for atomizing at least one liquid into droplets and means for guiding the formed droplets towards a surface of a hot material so that at least some of the droplets collide with the surface of the hot material and evaporate, thus removing thermal energy from the surface layer of the hot material.

[0005] The preferred embodiments of the invention are disclosed in the dependent claims.

[0006] The invention is based on the idea of cooling a material or product in tempering by using at least one liquid which is atomized into small droplets by means of one or more sprayers. The droplets are further conveyed to the surface of the hot material to be tempered so that the droplets collide with the surface of the hot material to be tempered. The droplets may be guided towards the surface of the hot material by using a gas flow, the cooling of the hot material being achieved by an aerosol that comprises the formed droplets. The droplets colliding with the hot surface of the material receive thermal energy from the hot material and evaporate quickly. In other words, liquid evaporates in separate droplets and from separate droplets so that no layer of liquid or pools consisting of a plural number of droplets are formed onto the material surface. In other words, when a droplet collides with the surface of the hot material, it evaporates in the collision or immediately thereafter. This is achieved by using sufficiently small droplets. The liquid is preferably coalesced into droplets having an average diameter smaller than or equal to 30 um. These extremely small droplets evaporate rapidly as they collide with the hot material, thus removing efficiently thermal energy from the hot material. In a preferred case the power of the collision on the surface of the hot material is sufficiently efficient for evaporating small droplets substantially in connection with the collision.

[0007] An advantage of the method and apparatus of the invention is that the use of small droplets for cooling hot material in a tempering process enables an energy efficient means for tempering a hot material. The small droplets allow a rapid and efficient heat transfer from a hot piece to be achieved. Uniform and rapid heat transfer is particularly important when large surfaces and thin products, such as thin glass, are to be tempered. Cooling produced with small droplets consumes significantly less energy than prior art air cooling and, moreover, a tempering apparatus based on the use of small droplets has a structure that is simpler to produce.

BRIEF DISCLOSURE OF THE FIGURES

[0008] In the following the invention will be disclosed in greater detail in connection with preferred embodiments, with reference to the enclosed drawings, in which:

[0009] FIG. 1 is a schematic view of the apparatus according to the invention for tempering material;

[0010] FIG. 2 is a schematic view of a sprayer for carrying out tempering according to the invention;

[0011] FIG. 3 is a schematic view of a second sprayer for carrying out tempering according to the invention; and

[0012] FIG. 4 is a schematic view of a second embodiment of the sprayer.

DETAILED DISCLOSURE OF THE INVENTION

[0013] Reference is made to FIG. 1, which discloses an embodiment of the apparatus of the invention that allows the method of the invention to be implemented. The apparatus 50 is used for tempering a moving hot material web 26. The material to be tempered may be for example metal, such as steel, glass, metal alloy or a ceramic material. Although FIG. 1 shows the tempering of a moving material web, the method and apparatus of the invention may be applied to the tempering of any material or product movable in any way. Alternatively, the material or product to be tempered may also be stationary and one or more sprayers may move. In accordance with the invention the apparatus 50 comprises a sprayer 22 that allows the one or more liquids to be atomized into small droplets. When necessary, the apparatus 50 may also com-
prise two or more sprayers 22. The liquid to be atomized with the sprayer 22 to be used in tempering is preferably water, although it may also be an alcohol, such as a mixture of ethanol, water and alcohol, or some other liquid mixture or emulsion comprising water and/or alcohol. Alternatively, it is also possible to use some other liquid suitable for cooling or tempering or a mixture of one or more liquids. The liquid to be atomized is conveyed to the sprayer 22 on a line 2 through a flow meter 27. Also a gas flow is conveyed to the sprayer 22 on a channel 20 and through a flow regulator 18. The sprayer 22 shown here is a gas dispersing sprayer, although an ultrasound sprayer or some other sprayer capable of producing sufficiently small droplets is also possible. The sprayer 22 atomizes liquid into small droplets 7 which are led by means of the gas flow, for example, towards the surface of the material 26 to be tempered.

[0014] The sprayer 22 may be in a chamber 14, which substantially separates the inner space of chamber 14 from the ambient atmosphere. Inert gas, for example, may be supplied into the chamber 14 from a gas conduit, which is preferably the gas conduit 20 used for atomizing the liquid. Alternatively, gas may be supplied into the chamber 14 from separate gas nozzles. The chamber 14 may also be provided with suction means for removing evaporated droplets 7 from the chamber 14. In other words, the apparatus 50 comprises means for guiding droplets 7 formed with the sprayer 22 towards the surface of the hot material 26. These means for guiding the formed droplets 7 towards the surface of the hot material may comprise one or more gas flows 20 atomizing at least one liquid, or one or more separate gas nozzles (not shown). The heating of the material to be tempered may take place in process step 24, for example, which is arranged upstream of the sprayer 22 and may consist of heating, working or a similar process step. In a preferred embodiment the tempering apparatus 50 of the invention is connected to a manufacturing or processing line of a material or product, such as a flat glass manufacturing line, the manufacturing line of some other glass product, the manufacturing line of steel or to the manufacturing or processing line of some other product or material. In the manufacturing line of flat glass the tempering apparatus 50 may be placed after the tin bath in the float line, for example, the temperature of the glass strip rising from the bath being 650° C. at the most. The temperature of the hot material arriving at the tempering may be from 850 to 450° C., for example. However, the temperature depends on the material to be tempered and the desired tempering properties.

[0015] In the disclosed invention hot material is tempered using small droplets 7 to produce the necessary rapid cooling, the droplets being guided to collide with the surface of the hot material 26 so that the droplets 7 collide with the surface of the hot material 26, as shown in FIG. 1. Sufficiently small size of the droplets 7 allows them to be made to collide with the surface of the hot material 26 at a sufficient speed. At the collision the droplets 7 receive thermal energy from the material 26, particularly from the surface layer thereof, and evaporate. To create efficient and rapid cooling the droplets 7 need to be sufficiently small. In order to provide sufficiently small droplets one or more sprayers 22 are arranged to atomize at least one liquid into droplets with an average diameter smaller than or equal to 30 um, preferably smaller than or equal to 10 um and more preferably smaller than or equal to 5 um. According to an embodiment the sprayer 22 has been achieved by producing droplets 7 with an average diameter of less than 3 um, and preferably even droplets 7 of an average diameter of less than 1 um. If the droplets 7 are too big, for example 100 um or more, the droplets 7 do not evaporate rapidly enough when they collide with the surface of the hot material 26 but form a liquid film on the surface of the hot material 26, or remain floating on the surface of the hot material 26. This slows down the cooling and the liquid film boils away from the surface of the hot material 26, thus forming a gas layer above the surface, which further slows down the cooling. The liquid remaining onto the surface of the hot material 26 also causes uneven cooling of the hot material 26 and uneven residual stresses. Further, a liquid film or a large drop left on the surface of the hot material 26 often leaves undesirable marks on the material surface. In addition, the speed of the large droplets often remains too low for a sufficiently efficient collision to be achieved on the surface of the hot material 26. The small droplets 7 may be generated using a gas dispersing sprayer 22 or an ultrasound sprayer, for example. However, a disadvantage with the ultrasound sprayer is its low droplet production rate and the need for a separate control gas for guiding the droplets 7 towards the surface of the hot material 26. In other words, for a good cooling to be achieved the droplets are to be sufficiently small in order to have a sufficiently small mass for a rapid evaporation and, moreover, the droplets are to be guided towards the surface of the hot material at a sufficient rate for an efficient collision to be achieved. In the present invention the small size of the droplets 7 and their sufficient speed causes the droplets 7 to collide substantially as separate droplets, thereby avoiding the formation of a liquid film or pools onto the surface of the hot material. The sufficient speed of the droplets 7 depends for example on the size of the droplets 7 and on the liquid used for the cooling and for forming the droplets 7.

[0016] The following shows by means of FIGS. 2, 3, and 4 examples of alternative sprayers 22, with which sufficiently small droplets 7 may be produced.

[0017] FIG. 2 shows a basic view of the sprayer 22. Liquid, such as water, used in tempering is fed into the sprayer producing ultra-small liquid droplets from a channel 25. Spraying gas, such as nitrogen IM2, is led to a gas channel 20. A distributing chamber 30 and flow impediments 32 distribute the spray flow evenly around the liquid channel 25, whereby the liquid atomizes into droplets in the spray nozzle 34. The droplet size of the aerosol atomized in the spray nozzle 34, or spray head 34, is relatively large. As the aerosol flows on, the flow impediments 36 alter the hydrodynamic properties of the aerosol flow and unexpectedly cause the droplet size of the aerosol to change into ultra-small droplets. The mechanism is based on both collision energy and pressure change caused by the flow impediments 36. In other words, the flow impediments 36 are arranged in such a manner that the droplets of the aerosol discharging from the spray head 34 collide into one or more flow impediments 36 and/or each other to reduce the droplet size of the aerosol. In addition or alternatively, the flow impediments 36 are arranged in such a manner that they generate into the aerosol flow discharging from the spray head 34 a pressure change and/or restriction to reduce the droplet size of the aerosol. With the arrangement, ultra-small droplets 7 discharge from the nozzle. The ultra-small droplets are further directed to the surface of the hot material 26. The droplets 7 evaporate as they collide with the surface of the hot material 26 and remove heat energy from the hot material 26.
According to what is stated above, the sprayer 22 of FIG. 2 atomizes at least one liquid into aerosol at the spray head 24 of the sprayer 22 by means of gas. The sprayer 22 has at least one liquid channel 25 for supplying at least one liquid to be atomized into the spray head 34 and at least one gas channel 20 for supplying at least one gas to the spray head 34 for spraying the liquid into an aerosol. The spraying gas atomizes the liquid into an aerosol in the spray head 34 especially as a result of the difference in the velocity of the spraying gas and liquid discharging from the spray head 34. The spray head 34 also comprises one or more flow impediments 36 for altering the hydrodynamic properties, such as velocity and pressure, of the aerosol flow discharging from the spray head 34 in such a manner that the droplet size of the aerosol diminishes. The sprayer 22 may be equipped with a spray chamber 35 in flow connection with the spray head 34, to which spray chamber the flow impediments 36 are formed. In FIG. 2, the spray chamber 36 is a tubular space, but may also be some other space. There may be one or more flow impediments 36 and they may be placed consecutively, side by side or in some other corresponding manner in relation to each other. The flow impediments 36 may for instance guide, slow, or restrict the aerosol flow. According to FIG. 2, the flow impediments 36 are provided on the inner walls of the spray chamber 34 in such a manner that they extend from the inner walls toward the inside of the spray chamber 34. Preferably, the flow impediments 36 are arranged in such a manner that the aerosol droplets discharging from the spray head 34 collide into one or more flow impediments 36 and/or each other to reduce the droplet size of the droplet spray. In addition to or alternatively, the flow impediments 36 are arranged to generate a pressure change and/or restriction in the aerosol flow discharging from the spray head 34 to reduce the droplet size of the droplet spray. By means of the flow impediments 36, the average aerodynamic diameter of the aerosol droplets discharging from the sprayer 22 becomes 10 micrometers, preferably 3 micrometers or less, and more preferably 1 micrometer or less.

FIG. 3 shows another sprayer 22 for generating small droplets. Two sprayers 2 directed substantially at each other are fastened to the body 1 of the sprayer 22. The sprayers 2 are arranged into the device directly toward each other as shown in FIG. 1. In other words, the sprayers 2 are preferably arranged essentially coaxially opposite each other in such a manner that their droplet sprays 4 essentially directly collide with each other. The device may comprise two or more sprayers 2. Preferably, the sprayers 2 are arranged in pairs to form one or more sprayer pairs in such a manner that the sprayers 2 of each sprayer pair are directed essentially directly, preferably coaxially, toward each other, whereby the droplet sprays 4 or each sprayer pair collide directly with each other. The sprayer pairs may further be arranged into the device for example consecutively or side by side in the vertical or horizontal direction.

A liquid 3 to be sprayed and spraying gas 8 are fed into the sprayer 2. The spraying gas 8 and liquid 3 are preferably fed into the sprayer 2 at different velocities, whereby the difference in velocity between the spraying gas 8 and liquid 3 at the output of the sprayer 2 cause the liquid 3 to spray, atomize, into a droplet spray 4 that consists of small droplets. The droplet sprays 4 collide with each other, whereby an aerosol consisting of very small droplets 7 is unexpectedly formed. The droplet spray 4 may in itself already form an aerosol. As droplet sprays directed essentially directly at each other collide, an aerosol is produced that does not essentially move, when the momentums of the droplet sprays 4 are essentially equal. The device may further be arranged to contain means for supplying at least two different liquids to at least two sprayers. In other words, the device may be formed in such a manner that the same or different liquids may be supplied to two or more sprayers 2. In other words, the same or different liquids may be supplied to the sprayers 2 of each sprayer pair, if desired. In addition, the same liquid or different liquids than in the other sprayer pairs can be used in at least two sprayer pairs. In such a case, each sprayer pair may produce a different spray or a similar spray as the sprayer pair beside it. Further, the sprayers 2 of the device may be adapted to produce droplet sprays 4 in which the droplets are substantially different or similar in their average droplet size. For instance, the geometry of the sprayers 2 or the velocity of the fluid 3 and spraying gas or the difference in velocity between them may all affect the size of the droplets. This makes it possible to produce an aerosol that is homogeneous or heterogeneous in droplet size.

The sprayer 22 preferably also comprises means for directing a gas flow from at least one direction to the collision point of the droplet sprays 4. This is preferably done by furnishing the device with a gas nozzle 5 for supplying gas from at least one direction to the collision point of the droplet sprays 4. Thus, by means of the gas flow, it is possible to move or transfer the aerosol generated at the collision point of the droplet sprays 4 into a required direction toward the surface of the hot material 26. Any gas may be used in the gas nozzle 5. In other words, it may be an inert gas, such as nitrogen, or a gas that reacts to the spray or aerosol. In the embodiment of FIG. 3, the gas nozzle 5 is arranged into the device in such a manner that the gas flow flows and collides substantially perpendicularly in relation to the droplet sprays 4.

Another embodiment of the sprayer 22 of FIG. 3 is shown in FIG. 4. Two sprayers 2 directed substantially at each other are mounted on the body 1 of the sprayer 22. A liquid 3 to be sprayed and spraying gas 8 are supplied to the sprayer 2. The difference in velocity between the spraying gas 8 and liquid 3 at the output of the sprayer 2 makes the liquid 3 atomize into droplet sprays 4 that comprise small droplets. The droplet sprays 4 collide with each other, whereby an aerosol made up of very small droplets 7 is unexpectedly formed. From a sprayer 12 fastened to the body 1 of the sprayer 22, a liquid 10 and atomizing gas 11 (together: aerosol) are also supplied to the collision point of the droplet sprays 4. The atomizing gas 11 then acts as a spraying gas for the liquid 10. The aerosol discharging from the sprayer 12 guides the formed droplets on toward the surface of the hot material 26.

It is apparent to a person skilled in the art that as technology advances, the basic idea of the invention may be implemented in many different manners. The invention and its embodiments are, thus, not limited to the examples described above, but may vary within the scope of the claims.

1. A method for tempering material, the method comprising atomizing at least one liquid into droplets, the formed droplets being guided towards a surface of a hot material so that at least some of the droplets collide with the surface of the hot material, wherein the droplets are formed and guided to the surface of the hot material in such a way that the droplets colliding with the surface of the hot material evaporate when they receive thermal energy from the surface layer of the hot material.
2. A method according to claim 1 of atomizing at least one liquid being into droplets whose average diameter is smaller than equal to 30 μm.
3. A method according to claim 1, wherein at least one liquid is atomized into droplets whose average diameter is smaller than equal to 10 μm.
4. A method according to claim 1, wherein at least one liquid is atomized into droplets whose average diameter is smaller than equal to 5 μm.
5. A method according to claim 1, wherein the at least one liquid is atomized by means of a gas flow or ultrasound.
6. A method according to claim 5, wherein the atomizing gas flow is used for guiding the droplets towards the surface of the hot material.
7. A method according to claim 1, wherein the droplets are guided towards the surface of the hot material using a separate guiding gas flow.
8. A method according to claim 1, wherein the at least one liquid is atomized into two or more droplet jets by guiding at least two droplet jets substantially perpendicularly towards one another to make the droplet jets collide directly with one another.
9. A method according to claim 1, comprising guiding a gas flow from at least one direction to the collision point of the droplet jets for forming an aerosol and for guiding it towards the surface of the hot material.
10. A method according to claim 1, wherein the method comprises the steps of atomizing at least one liquid raw material by at least one gas dispersing sprayer into an aerosol that is released from the spray end of the sprayer; decreasing the droplet size of the aerosol released from the spray end of the sprayer by changing the hydrodynamic properties of the aerosol flow by means of flow impediments; and guiding the aerosol onto the surface of the material so that at least some of the droplets in the aerosol collide with the surface of the hot material and evaporate upon receiving thermal energy from the surface layer of the hot material.
11. A method according to claim 10, comprising reducing the average droplet size in the aerosol by changing the hydrodynamic properties of the aerosol flow by means of flow impediments so that the aerosol droplets released from the spray end collide with one or more flow impediments and/or one another to reduce the droplet size of the aerosol.
12. A method according to claim 10, comprising reducing the average droplet size in the aerosol by changing the hydrodynamic properties of the aerosol flow by means of flow impediments so that they cause a pressure change and/or a throttle in the aerosol flow released from the sprayhead for reducing the droplet size.
13. A method according to claim 1, wherein the temperature of the hot material before the tempering is 450 to 850 °C.
14. A method according to claim 1, wherein the hot material is a glass, metal, metal alloy, ceramic material.
15. A method according to claim 1, comprising using always water, alcohol, mixture of water and alcohol, some other liquid mixture or emulsion suitable for cooling.
16. An apparatus for tempering a material, the apparatus comprising one or more sprayer for atomizing at least one liquid into droplets, and means for guiding the formed droplets towards a surface of a hot material so that at least some of the droplets collide with a surface of the hot material, wherein the apparatus is configured to produce droplets and to guide formed droplets to the surface of the hot material so that the droplets collide with the surface of the hot material in the form of droplets, the droplets evaporating when they receive thermal energy from the surface layer of the hot material.
17. An apparatus according to claim 16, wherein one or more sprayers are configured to atomize at least one liquid into droplets having an average diameter smaller than or equal to 30 μm.
18. An apparatus according to claim 16, wherein one or more sprayers are configured to atomize at least one liquid into droplets having an average diameter smaller than or equal to 10 μm.
19. An apparatus according to claim 16, wherein the at least one liquid is atomized into droplets having an average aerodynamic diameter smaller than or equal to 5 μm.
20. An apparatus according to claim 16, wherein the apparatus is configured to atomize at least one liquid flow by a gas flow or ultrasound.
21. An apparatus according to claim 20, wherein the means for guiding the formed droplets towards the surface of the hot material comprise one or more gas flows atomizing at least one liquid.
22. An apparatus according to claim 16, wherein the means for guiding the formed droplets towards the surface of the hot material comprise one or more gas nozzles.
23. An apparatus according to claim 16, wherein at least two sprayers are arranged substantially perpendicularly directed towards one another so that the droplet jets they form collide with one another perpendicularly.
24. An apparatus according to claim 23, wherein it comprises at least one gas nozzle for supplying gas from at least one direction to the point where the droplet jets collide for guiding the droplets towards the surface of the hot material.
25. An apparatus according to claim 16, wherein the apparatus comprises at least one gas dispersing sprayer for atomizing liquid at the spray end of the sprayer into gas, the sprayer further comprising one or more flow impediments for changing the hydrodynamic properties of the aerosol flow released from the spray end so that the average droplet size in the aerosol changes.
26. An apparatus according to claim 25, wherein the sprayer comprises a spray chamber with flow impediments formed therein and in flow connection to the spray head.
27. An apparatus according to claim 26, wherein the flow impediments have been formed onto the inner walls of the spray chamber so that they protrude from the inner walls into the spray chamber.
28. An apparatus according to claim 25, wherein the flow impediments have been arranged so that the aerosol droplets released from the spray end collide with one or more flow impediments and/or one another for reducing the droplet size in the aerosol.
29. An apparatus according to claim 25, wherein the flow impediments have been arranged so that they cause a pressure change and/or throttle in the aerosol flow released from the spray head for reducing the droplet size of the aerosol.
30. An apparatus according to claim 16, wherein at least one atomizing liquid used is water, alcohol, mixture of water and alcohol or some other liquid mixture or emulsion comprising water and/or alcohol.

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